

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11)

EP 0 866 569 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
23.09.1998 Bulletin 1998/39

(51) Int Cl. 6: H04B 7/185

(21) Application number: 98302044.7

(22) Date of filing: 18.03.1998

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC
NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 18.03.1997 US 819310

(71) Applicant: Globalstar L.P.
San Jose, California 95134 (US)

(72) Inventors:

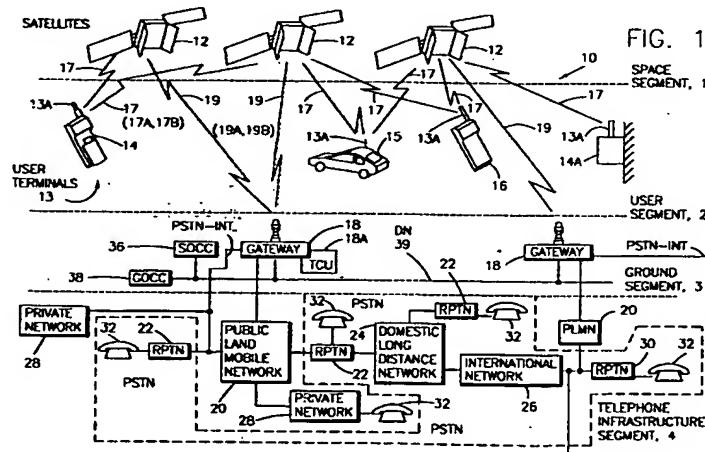
- Wiedeman, Robert A.
Los Altos, California 94074 (US)
- Monte, Paul a.
San Jose, California 95117 (US)

(74) Representative: Vaufruard, John Charles
Elkington and Fife
Prospect House
8 Pembroke Road
Sevenoaks, Kent TN13 1XR (GB)

(54) **Satellite communications system having distributed user assignment and resource assignment with terrestrial gateways**

(57) A satellite communications system (10) includes at least one satellite (12); a system controller (38); a plurality of gateways (18); and at least one user terminal (13) operable for bidirectionally communicating with at least one of the gateways through the at least one satellite. Individual ones of the plurality of gateways are bidirectionally coupled to at least one terrestrial communications system (4) and act to couple the user terminal to the terrestrial communication system through at least one satellite. In accordance with an aspect of this invention, individual ones of the plurality of gateways are operable for receiving an access request from the user terminal, through at least one satellite, and are further operable for notifying the requesting user ter-

minal, through at least one satellite, that the user terminal is one of accepted by the gateway for establishing a communication link and not accepted by the gateway for establishing the communication link. A gateway that does not accept a user terminal can indicate to the user terminal, based at least in part on a determined location of the user terminal, an identification of a gateway to which the user terminal should apply for access or log-in purposes. The system further includes a data network (39) that interconnects the system controller and the plurality of gateways. The data network may be conveyed by and embodied in one of a wired network, a wireless network, and a combination of a wired network and a wireless network.



Description

This invention relates generally to satellite communications systems and, in particular, to resource assignment techniques for satellite communication systems.

Our U.S. Patent No. 5,448,623, issued September 5, 1995, entitled "Satellite Telecommunications System Using Network Coordinating Gateways Operative with a Terrestrial Communication System", by R.A. Wiedemann and P.A. Monte, describes a wireless telephone system capable of servicing a roaming wireless telephone user. The system includes a satellite communications system having at least one and preferably a constellation of orbiting satellites; at least one terrestrial-based gateway having access to a database of users; at least one network coordinating gateway within at least one satellite service area; a single network control center, and a plurality of terrestrial communications' links. A terrestrial data network links together the terrestrial-based components of the system, and is used for communicating, for example, system control and status information amongst the terrestrial-based components.

The system operates by effecting communication between a terrestrial wireless telephone end user transceiver and a terrestrial communications link via a relay through a single satellite or a succession of single relay satellites. The relay satellite may be in motion relative to the end user transceiver and the terrestrial communications link. The terrestrial-based gateway cooperates with the network database to effect hand-off from a first orbiting satellite to a second orbiting satellite. The satellites orbiting near the earth need only translate signals from the gateways and from the users to the gateways, without satellite-based control. That is, the satellites function to receive a ground-originated transmission from a gateway of a user transceiver, frequency translate the received transmission, and to transmit the frequency translated transmission back to the ground.

This invention seeks to provide improvements to the satellite-based communications system that is described in U.S. Patent No. 5,448,623.

According to one aspect of the invention there is provided a satellite communications system having at least one satellite; a system controller; a plurality of gateways; and at least one user terminal operable for bidirectionally communicating with at least one of the gateways through at least one satellite. Individual ones of the plurality of gateways are bidirectionally coupled to at least one terrestrial communications system and act to couple the user terminal to the terrestrial communication system through at least one satellite.

Individual ones of the plurality of gateways may be operable for receiving an access request from the user terminal, through at least one satellite, and are further operable for notifying the requesting user terminal, through at least one satellite, that the user terminal is one of accepted by the gateway for establishing a communication link or not accepted by the gateway for es-

tablishing the communication link.

Individual ones of the plurality of gateways may bi-directionally coupled to a database indicating the identities of active, logged-in user terminals. The gateways are operable for receiving a log-in request from a user terminal, through at least one satellite, and are further operable for notifying the requesting user terminal, through at least one satellite, of one of: (a) that the user terminal's log-in request has been accepted by the gateway for storage in the database; and (b) that the user terminal's log-in request has not been accepted by the gateway.

A gateway that does not accept a user terminal can indicate to the user terminal, based at least in part on a determined location of the user terminal, an identification of a gateway or gateways to which the user terminal should apply for access or log-in purposes.

The system may include a data network that interconnects the system controller and the plurality of gateways. The data network is employed by the system controller and by the gateways for a number of purposes, including selectively assigning system resources to individual ones of the plurality of gateways based at least in part on a predicted demand for system resources.

The data network may be conveyed by and embodied in one of a wireless network and a combination of wired network and a wireless network. For example, all or a portion of the data network can be embodied within wireless links that are established between gateways, via the at least one communication satellite.

In order that the invention and its various other preferred features may be understood more easily, some embodiments thereof will now be described, by way of example only, with reference to the drawings, in which:-

Fig. 1 is block diagram of a satellite communication system that is constructed and operated in accordance with a presently preferred embodiment of this invention;

Fig. 2 is a block diagram of one of the gateways of Fig. 1;

Fig. 3A is a block diagram of the communications payload of one of the satellites of Fig. 1;

Fig. 3B illustrates a portion of a beam pattern that is associated with one of the satellites of Fig. 1;

Fig. 4A is a diagram of a first embodiment of a system data network that may be wholly or partially embodied within RF links interconnecting non-geosynchronous satellites and terrestrial gateways;

Fig. 4B is a diagram of a second embodiment of a system data network that may be wholly or partially embodied within RF links interconnecting satellites and terrestrial gateways, wherein at least one of the

satellites is a geosynchronous satellite;

Figure 5 illustrates a user terminal, three service areas, beams from three satellites, and three gateways, and is useful in explaining a method in accordance with this invention;

Figures 6A and 6B are a flow chart that illustrates a first method in accordance with this invention;

Figure 7 is a flow chart that illustrates a second method in accordance with this invention; and

Figure 8 is a block diagram of a user terminal that is adapted for carrying out the invention.

Fig. 1 illustrates a presently preferred embodiment of a satellite communication system 10 that is suitable for use with the presently preferred embodiment of this invention. Before describing this invention in detail, a description will first be made of the communication system 10 so that a more complete understanding may be had of the present invention.

The communications system 10 may be conceptually subdivided into a plurality of segments 1, 2, 3 and 4. Segment 1 is referred to herein as a space segment, segment 2 as a user segment, segment 3 as a ground (terrestrial) segment, and segment 4 as a telephone system infrastructure segment.

It should be noted that the ground or terrestrial segment 3 is intended to encompass all components that are located anywhere on or adjacent to (including aircraft) the surface of the earth. Any components that are located on or over bodies of water are thus considered to be included within the terrestrial segment.

In the presently preferred embodiment of this invention there are a total of 48 satellites in, by example, a 1414 km Low Earth Orbit (LEO). The satellites 12 are distributed in eight orbital planes with six equally-spaced satellites per plane (Walker constellation). The orbital planes are inclined at 52 degrees with respect to the equator and each satellite completes an orbit once every 114 minutes. This approach provides approximately full-earth coverage with, preferably, at least two satellites in view at any given time from a particular user location between about 70 degree south latitude and about 70 degree north latitude. As such, a user is enabled to communicate to or from nearly any point on the earth's surface within a gateway (GW) 18 coverage area to or from other points on the earth's surface (by way of the PSTN), via one or more gateways 18 and one or more of the satellites 12, possibly also using a portion of the telephone infrastructure segment 4.

It is noted at this point that the foregoing and ensuing description of the system 10 represents but one suitable embodiment of a communication system within which the teaching of this invention may find use. That is, the specific details of the communication system are

not to be read or construed in a limiting sense upon the practice of this invention.

Continuing now with a description of the system 10, a soft transfer (handoff) process between satellites 12, and also between individual ones of 16 spot beams transmitted by each satellite (Fig. 3B), provides unbroken communications via a spread spectrum (SS), code division multiple access (CDMA) technique. The presently preferred SS-CDMA technique is similar to the TIA/EIA Interim Standard, "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" TIA/EIA/IS-95, July 1993, although other spread spectrum and CDMA techniques and protocols can be employed. In general, any multiple access scheme can be employed, such as CDMA, TDMA, FDMA, or a combination of such techniques.

The low earth orbits permit low-powered fixed or mobile user terminals 13 to communicate via the satellites 12, each of which functions, in a presently preferred embodiment of this invention, solely as a "bent pipe" repeater to receive a communications traffic signal (such as speech and/or data) from a user terminal 13 or from a gateway 18, convert the received communications traffic signal to another frequency band, and to then retransmit the converted signal. That is, no on-board signal processing of a received communications traffic signal occurs, and the satellite 12 does not become aware of any intelligence that a received or transmitted communications traffic signal may be conveying.

Furthermore, there need be no direct communication link or links between the satellites 12. That is, each of the satellites 12 receives a signal only from a transmitter located in the user segment 2 or from a transmitter located in the ground segment 3, and transmits a signal only to a receiver located in the user segment 2 or to a receiver located in the ground segment 3.

The user segment 2 may include a plurality of types of user terminals 13 that are adapted for communication with the satellites 12. The user terminals 13 include, for example, a plurality of different types of fixed and mobile user terminals including, but not limited to, handheld mobile radio-telephones 14, vehicle mounted mobile radio-telephones 15, paging/messaging-type devices 16, and fixed radio-telephones 14A. The user terminals 13 are preferably provided with omnidirectional antennas 13A for bidirectional communication via one or more of the satellites 12.

It is noted that the fixed radio-telephones 14A may employ a directional antenna. This is advantageous in that it enables a reduction in interference with a consequent increase in the number of users that can be simultaneously serviced with one or more of the satellites 12.

It is further noted that the user terminals 13 may be dual use devices that include circuitry for also communicating with a terrestrial Cellular system.

Referring also to Fig. 3A, the user terminals 13 (Fig-

ure 1) may be capable of operating in a full duplex mode and communicate via, for example, L-band RF links (up-link or return link 17B) and S-band RF links (downlink or forward link 17A), through return and forward satellite transponders 12A and 12B, respectively. The return L band RF links 17B may operate within a frequency range of 1.61 GHz to 1.625 GHz, a bandwidth of 16.5 MHz, and are modulated with packetized digital voice signals and/or data signals in accordance with the preferred spread spectrum technique. The forward S band RF links 17A may operate within a frequency range of 2.485 GHz to 2.5 GHz, a bandwidth of 16.5 MHz. The forward RF links 17A are also modulated at a gateway 18 with packetized digital voice signals and/or data signals in accordance with the spread spectrum technique.

The 16.5 MHz bandwidth of the forward link is partitioned into 13 channels with up to, for example, 128 users being assigned per channel. The return link may have various bandwidths, and a given user terminal 13 may or may not be assigned a different channel than the channel assigned on the forward link. However, when operating in the diversity reception mode on the return link (receiving from two or more satellites 12), the user is assigned the same forward channel for each of the satellites and the same or a different channel for the return link.

The ground segment 3 (Figure 1) includes at least one but generally a plurality of the gateways 18 that communicate with the satellites 12 via, for example, a full duplex C band RF link 19 (forward link 19A to the satellite), return link 19B (from the satellite)) that operates within a range of frequencies generally above 3 GHz and preferably in the C-band. The C-band RF links bi-directionally convey the communication feeder links, and also convey satellite commands to the satellites and telemetry information from the satellites. The forward feeder link 19A may operate in the band of 5 GHz to 5.25 GHz, while the return feeder link 19B may operate in the band of 6.875 GHz to 7.0756 GHz.

Satellite feeder link antennas 12G and 12H are preferably wide coverage antennas that subtend a maximum earth coverage area as seen from the LEO satellite 12. In the presently preferred embodiment of the communication system 10 the angle subtended from a given LEO satellite 12 (assuming 10° elevation angles from the earth's surface) is approximately 107°. This yields a coverage zone that is approximately 3600 miles in diameter.

The L-band and the S-band antennas are multiple beam antennas that provide coverage within an associated terrestrial service region. The L-band and S-band antennas 12D and 12C, respectively, are preferably congruent with one another, as depicted in Figure 3B. That is, the transmit and receive beams from the spacecraft cover the same area on the earth's surface, although this feature is not critical to the operation of the system 10.

As an example, several thousand full duplex com-

munications may occur through a given one of the satellites 12. In accordance with a feature of the system 10, two or more satellites 12 may each convey the same communication between a given user terminal 13 and one of the gateways 18. This mode of operation, as described in detail below, thus provides for diversity combining at the respective receivers, leading to an increased resistance to fading and facilitating the implementation of a soft handoff procedure.

It is pointed out that all of the frequencies, bandwidths and the like that are described herein are representative of but one particular system. Other frequencies and bands of frequencies may be used with no change in the principles being discussed. As but one example, the feeder links between the gateways and the satellites may use frequencies in a band other than the C-band (approximately 3 GHz to approximately 7 GHz), for example the Ku band (approximately 10 GHz to approximately 15 GHz) or the Ka band (above approximately 15 GHz).

10 The gateway 18 function to couple the communications payload or transponders 12A and 12B (Fig 3A) of the satellites 12 to the telephone infrastructure segment 4. The transponders 12A and 12B include an L-band receive antenna 12C, S-band transmit antenna 12B, C-band power amplifier 12E, C-band low noise amplifier 12F, C-band antennas 12C and 12H, L band to C band frequency conversion section 12I, and C band to S band frequency conversion section 12J. The satellite 12 also includes a master frequency generator 12K and command and telemetry equipment 12L.

15 Reference in this regard may also be had to U.S. Patent No. 5,422,647, by E. Hirshfield and C.A. Tsao, entitled "Mobile Communications Satellite Payload", which discloses one type of communications satellite payload that is suitable for use with the teaching of this invention.

20 The telephone infrastructure segment 4 comprises existing telephone systems and includes Public Land Mobile Network (PLMN) gateways 20, local telephone exchanges such as regional public telephone networks (RPTN) 22 or other local telephone service providers, domestic long distance networks 24, international networks 26, private networks 28 and other RPTNs 30. The communication system 10 operates to provide bidirectional voice and/or data communication between the user segment 2 and Public Switched Telephone Network (PSTN) telephones 32 and non-PSTN telephones 32 of the telephone infrastructure segment 4, or other user terminals of various types, which may be private networks.

25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 1225 1230 1235 1240 1245 1250 1255 1260 1265 1270 1275 1280 1285 1290 1295 1300 1305 1310 1315 1320 1325 1330 1335 1340 1345 1350 1355 1360 1365 1370 1375 1380 1385 1390 1395 1400 1405 1410 1415 1420 1425 1430 1435 1440 1445 1450 1455 1460 1465 1470 1475 1480 1485 1490 1495 1500 1505 1510 1515 1520 1525 1530 1535 1540 1545 1550 1555 1560 1565 1570 1575 1580 1585 1590 1595 1600 1605 1610 1615 1620 1625 1630 1635 1640 1645 1650 1655 1660 1665 1670 1675 1680 1685 1690 1695 1700 1705 1710 1715 1720 1725 1730 1735 1740 1745 1750 1755 1760 1765 1770 1775 1780 1785 1790 1795 1800 1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130 2135 2140 2145 2150 2155 2160 2165 2170 2175 2180 2185 2190 2195 2200 2205 2210 2215 2220 2225 2230 2235 2240 2245 2250 2255 2260 2265 2270 2275 2280 2285 2290 2295 2300 2305 2310 2315 2320 2325 2330 2335 2340 2345 2350 2355 2360 2365 2370 2375 2380 2385 2390 2395 2400 2405 2410 2415 2420 2425 2430 2435 2440 2445 2450 2455 2460 2465 2470 2475 2480 2485 2490 2495 2500 2505 2510 2515 2520 2525 2530 2535 2540 2545 2550 2555 2560 2565 2570 2575 2580 2585 2590 2595 2600 2605 2610 2615 2620 2625 2630 2635 2640 2645 2650 2655 2660 2665 2670 2675 2680 2685 2690 2695 2700 2705 2710 2715 2720 2725 2730 2735 2740 2745 2750 2755 2760 2765 2770 2775 2780 2785 2790 2795 2800 2805 2810 2815 2820 2825 2830 2835 2840 2845 2850 2855 2860 2865 2870 2875 2880 2885 2890 2895 2900 2905 2910 2915 2920 2925 2930 2935 2940 2945 2950 2955 2960 2965 2970 2975 2980 2985 2990 2995 3000 3005 3010 3015 3020 3025 3030 3035 3040 3045 3050 3055 3060 3065 3070 3075 3080 3085 3090 3095 3100 3105 3110 3115 3120 3125 3130 3135 3140 3145 3150 3155 3160 3165 3170 3175 3180 3185 3190 3195 3200 3205 3210 3215 3220 3225 3230 3235 3240 3245 3250 3255 3260 3265 3270 3275 3280 3285 3290 3295 3300 3305 3310 3315 3320 3325 3330 3335 3340 3345 3350 3355 3360 3365 3370 3375 3380 3385 3390 3395 3400 3405 3410 3415 3420 3425 3430 3435 3440 3445 3450 3455 3460 3465 3470 3475 3480 3485 3490 3495 3500 3505 3510 3515 3520 3525 3530 3535 3540 3545 3550 3555 3560 3565 3570 3575 3580 3585 3590 3595 3600 3605 3610 3615 3620 3625 3630 3635 3640 3645 3650 3655 3660 3665 3670 3675 3680 3685 3690 3695 3700 3705 3710 3715 3720 3725 3730 3735 3740 3745 3750 3755 3760 3765 3770 3775 3780 3785 3790 3795 3800 3805 3810 3815 3820 3825 3830 3835 3840 3845 3850 3855 3860 3865 3870 3875 3880 3885 3890 3895 3900 3905 3910 3915 3920 3925 3930 3935 3940 3945 3950 3955 3960 3965 3970 3975 3980 3985 3990 3995 4000 4005 4010 4015 4020 4025 4030 4035 4040 4045 4050 4055 4060 4065 4070 4075 4080 4085 4090 4095 4100 4105 4110 4115 4120 4125 4130 4135 4140 4145 4150 4155 4160 4165 4170 4175 4180 4185 4190 4195 4200 4205 4210 4215 4220 4225 4230 4235 4240 4245 4250 4255 4260 4265 4270 4275 4280 4285 4290 4295 4300 4305 4310 4315 4320 4325 4330 4335 4340 4345 4350 4355 4360 4365 4370 4375 4380 4385 4390 4395 4400 4405 4410 4415 4420 4425 4430 4435 4440 4445 4450 4455 4460 4465 4470 4475 4480 4485 4490 4495 4500 4505 4510 4515 4520 4525 4530 4535 4540 4545 4550 4555 4560 4565 4570 4575 4580 4585 4590 4595 4600 4605 4610 4615 4620 4625 4630 4635 4640 4645 4650 4655 4660 4665 4670 4675 4680 4685 4690 4695 4700 4705 4710 4715 4720 4725 4730 4735 4740 4745 4750 4755 4760 4765 4770 4775 4780 4785 4790 4795 4800 4805 4810 4815 4820 4825 4830 4835 4840 4845 4850 4855 4860 4865 4870 4875 4880 4885 4890 4895 4900 4905 4910 4915 4920 4925 4930 4935 4940 4945 4950 4955 4960 4965 4970 4975 4980 4985 4990 4995 5000 5005 5010 5015 5020 5025 5030 5035 5040 5045 5050 5055 5060 5065 5070 5075 5080 5085 5090 5095 5100 5105 5110 5115 5120 5125 5130 5135 5140 5145 5150 5155 5160 5165 5170 5175 5180 5185 5190 5195 5200 5205 5210 5215 5220 5225 5230 5235 5240 5245 5250 5255 5260 5265 5270 5275 5280 5285 5290 5295 5300 5305 5310 5315 5320 5325 5330 5335 5340 5345 5350 5355 5360 5365 5370 5375 5380 5385 5390 5395 5400 5405 5410 5415 5420 5425 5430 5435 5440 5445 5450 5455 5460 5465 5470 5475 5480 5485 5490 5495 5500 5505 5510 5515 5520 5525 5530 5535 5540 5545 5550 5555 5560 5565 5570 5575 5580 5585 5590 5595 5600 5605 5610 5615 5620 5625 5630 5635 5640 5645 5650 5655 5660 5665 5670 5675 5680 5685 5690 5695 5700 5705 5710 5715 5720 5725 5730 5735 5740 5745 5750 5755 5760 5765 5770 5775 5780 5785 5790 5795 5800 5805 5810 5815 5820 5825 5830 5835 5840 5845 5850 5855 5860 5865 5870 5875 5880 5885 5890 5895 5900 5905 5910 5915 5920 5925 5930 5935 5940 5945 5950 5955 5960 5965 5970 5975 5980 5985 5990 5995 6000 6005 6010 6015 6020 6025 6030 6035 6040 6045 6050 6055 6060 6065 6070 6075 6080 6085 6090 6095 6100 6105 6110 6115 6120 6125 6130 6135 6140 6145 6150 6155 6160 6165 6170 6175 6180 6185 6190 6195 6200 6205 6210 6215 6220 6225 6230 6235 6240 6245 6250 6255 6260 6265 6270 6275 6280 6285 6290 6295 6300 6305 6310 6315 6320 6325 6330 6335 6340 6345 6350 6355 6360 6365 6370 6375 6380 6385 6390 6395 6400 6405 6410 6415 6420 6425 6430 6435 6440 6445 6450 6455 6460 6465 6470 6475 6480 6485 6490 6495 6500 6505 6510 6515 6520 6525 6530 6535 6540 6545 6550 6555 6560 6565 6570 6575 6580 6585 6590 6595 6600 6605 6610 6615 6620 6625 6630 6635 6640 6645 6650 6655 6660 6665 6670 6675 6680 6685 6690 6695 6700 6705 6710 6715 6720 6725 6730 6735 6740 6745 6750 6755 6760 6765 6770 6775 6780 6785 6790 6795 6800 6805 6810 6815 6820 6825 6830 6835 6840 6845 6850 6855 6860 6865 6870 6875 6880 6885 6890 6895 6900 6905 6910 6915 6920 6925 6930 6935 6940 6945 6950 6955 6960 6965 6970 6975 6980 6985 6990 6995 7000 7005 7010 7015 7020 7025 7030 7035 7040 7045 7050 7055 7060 7065 7070 7075 7080 7085 7090 7095 7100 7105 7110 7115 7120 7125 7130 7135 7140 7145 7150 7155 7160 7165 7170 7175 7180 7185 7190 7195 7200 7205 7210 7215 7220 7225 7230 7235 7240 7245 7250 7255 7260 7265 7270 7275 7280 7285 7290 7295 7300 7305 7310 7315 7320 7325 7330 7335 7340 7345 7350 7355 7360 7365 7370 7375 7380 7385 7390 7395 7400 7405 7410 7415 7420 7425 7430 7435 7440 7445 7450 7455 7460 7465 7470 7475 7480 7485 7490 7495 7500 7505 7510 7515 7520 7525 7530 7535 7540 7545 7550 7555 7560 7565 7570 7575 7580 7585 7590 7595 7600 7605 7610 7615 7620 7625 7630 7635 7640 7645 7650 7655 7660 7665 7670 7675 7680 7685 7690 7695 7700 7705 7710 7715 7720 7725 7730 7735 7740 7745 7750 7755 7760 7765 7770 7775 7780 7785 7790 7795 7800 7805 7810 7815 7820 7825 7830 7835 7840 7845 7850 7855 7860 7865 7870 7875 7880 7885 7890 7895 7900 7905 7910 7915 7920 7925 7930 7935 7940 7945 7950 7955 7960 7965 7970 7975 7980 7985 7990 7995 8000 8005 8010 8015 8020 8025 8030 8035 8040 8045 8050 8055 8060 8065 8070 8075 8080 8085 8090 8095 8100 8105 8110 8115 8120 8125 8130 8135 8140 8145 8150 8155 8160 8165 8170 8175 8180 8185 8190 8195 8200 8205 8210 8215 8220 8225 8230 8235 8240 8245 8250 8255 8260 8265 8270 8275 8280 8285 8290 8295 8300 8305 8310 8315 8320 8325 8330 8335 8340 8345 8350 8355 8360 8365 8370 8375 8380 8385 8390 8395 8400 8405 8410 8415 8420 8425 8430 8435 8440 8445 8450 8455 8460 8465 8470 8475 8480 8485 8490 8495 8500 8505 8510 8515 8520 8525 8530 8535 8540 8545 8550 8555 8560 8565 8570 8575 8580 8585 8590 8595 8600 8605 8610 8615 8620 8625 8630 8635 8640 8645 8650 8655 8660 8665 8670 8675 8680 8685 8690 8695 8700 8705 8710 8715 8720 8725 8730 8735 8740 8745 8750 8755 8760 8765 8770 8775 8780 8785 8790 8795 8800 8805 8810 8815 8820 8825 8830 8835 8840 8845 8850 8855 8860 8865 8870 8875 8880 8885 8890 8895 8900 8905 8910 8915 8920 8925 8930 8935 8940 8945 8950 8955 8960 8965 8970 8975 8980 8985 8990 8995 9000 9005 9010 9015 9020 9025 9030 9035 9040 9045 9050 9055 9060 9065 9070 9075 9080 9085 9090 9095 9100 9105 9110 9115 9120 9125 9130 9135 9140 9145 9150 9155 9160 9165 9170 9175 9180 9185 9190 9195 9200 9205 9210 9215 9220 9225 9230 9235 9240 9245 9250 9255 9260 9265 9270 9275 9280 9285 9290 9295 9300 9305 9310 9315 9320 9325 9330 9335 9340 9345 9350 9355 9360 9365 9370 9375 9380 9385 9390 9395 9400 9405 9410 9415 9420 9425 9430 9435 9440 9445 9450 9455 9460 9465 9470 9475 9480 9485 9490 9495 9500 9505 9510 9515 9520 9525 9530 9535 9540 9545 9550 9555 9560 9565 9570 9575 9580 9585 9590 9595 9600 9605 9610 9615 9620 9625 9630 9635 9640 9645 9650 9655 9660 9665 9670 9675 9680 9685 9690 9695 9700 9705 9710 9715 9720 9725 9730 9735 9740 9745 9750 9755 9760 9765 9770 9775 9780 9785 9790 9795 9800 9805 9810 9815 9820 9825 9

nications system 10 provides overall system control functions.

Fig. 2 shows one of the gateways 18 in greater detail. Each gateway 18 includes up to four dual polarization RF C-band sub-systems each comprising a dish antenna 40, antenna driver 42 and pedestal 42A low noise receivers 44, and high power amplifiers 46. All of these components may be located within a radome structure to provide environmental protection.

The gateway 18 further includes down converters 48 and up converters 50 for processing the received and transmitted RF carrier signals, respectively. The down converters 48 and the up converters 50 are connected to a CDMA sub-system 52 which, in turn, is coupled to the Public Switched Telephone Network (PSTN) through a PSTN interface 54. As an option, the PSTN could be bypassed by using satellite-to-satellite links.

The CDMA sub-system 52 includes a signal summer/switch unit 52A a Gateway Transceiver Subsystem (GTS) 52B a GTS Controller 52C a CDMA Interconnect Subsystem (CIS) 52D and a Selector Bank Subsystem (SBS) 52E The CDMA sub-system 52 is controlled by a Base Station Manager (BSM) 52F and functions in a manner similar to a CDMA-compatible (for example, an IS-95 compatible) base station. The CDMA sub-system 52 also includes the required frequency synthesizer 52G and a Global Positioning System (GPS) receiver 52H

The PSTN interface 54 includes a PSTN Service Switch Point (SSP) 54A a Call Control Processor (CCP) 54B a Visitor Location Register (VLR) 54C and a protocol interface 54D to a Home Location Register (HLR). The HLR may be located in the cellular gateway 20 (Fig. 1) or, optionally, in the PSTN interface 54.

The gateway 18 is connected to telecommunication networks through a standard interface made through the SSP 54A The gateway 18 provides an interface, and connects to the PSTN via Primary Rate Interface (PRI), or other suitable means. The gateway 18 is further capable of providing a direct connection to a Mobile Switching Center (MSC).

The gateway 18 provides SS-7 ISDN fixed signalling to the CCP 54B On the gateway-side of this interface, the CCP 54B interfaces with the CIS 52D and hence to the CDMA sub-system 52. The CCP 54B provides protocol translation functions for the system Air Interface (AI), which may be similar to the IS-95 Interim Standard for CDMA communications.

Blocks 54C and 54D generally provide an interface between the gateway 18 and an external cellular telephone network that is compatible, for example, with the IS-41 (North American Standard, AMPS) or the GSM (European Standard, MAP) cellular systems and, in particular, to the specified methods for handling roamer, that is, users who place calls outside of their home system. The gateway 18 supports user terminal authentication for system 10/AMPS phones and for system 10/GSM phones. In service areas where there is no ex-

isting telecommunications infrastructure, an HLR can be added to the gateway 18 and interfaced with the SS-7 signalling interface.

A user making a call out of the user's normal service area (a roamer) is accommodated by the system 10 if authorized. In that a roamer may be found in any environment, a user may employ the same terminal equipment to make a call from anywhere in the world, and the necessary protocol conversions are made transparently by the gateway 18. The protocol interface 54D is bypassed when not required to convert, for example, GSM to AMPS.

It is within the scope of the teaching of this invention to provide a dedicated, universal interface to the cellular gateways 20, in addition to or in place of the conventional "A" interface specified for GSM mobile switching centers and vendor-proprietary interfaces to IS-41 mobile switching centers. It is further within the scope of this invention to provide an interface directly to the PSTN, as indicated in Fig. 1 as the signal path designated PSTN-INT. It is also within the scope of this invention to provide one or more gateways that are not connected to any cellular system and/or PSTN.

Overall gateway control is provided by gateway controller 56 which includes an interface 56A to the above-mentioned Data Network (DN) 39 and an interface 56B to a Service Provider Control Center (SPCC) 60. The gateway controller 56 is generally interconnected to the gateway 18 through the BSM 52F and through RF controllers 43 associated with each of the antennas 40. The gateway controller 56 is further coupled to a database 62, such as a database of users, satellite ephemeris data, etc., and to an I/O unite 64, such as a display and keyboard, that enables service personnel to gain access to the gateway controller 56. The data network 39 is also bidirectionally interfaced to a Telemetry and Command (T&C) unit 66 (Fig. 1).

The function of the GOCC 38 is to plan and control satellite utilization by the gateways 18, and to coordinate this utilization with the SOCC 36. In general, the GOCC 38 analyses trends, generates traffic plans, allocates satellite 12 and system resources (such as, but not limited to, power and channel allocations), monitors the performance of the overall system 10, and issues system resources utilization instructions, via the DN 39, to the gateways 18 in real time or in advance.

The SOCC 36 operates to maintain and monitor orbits, to relay satellite usage information to the gateway for input to the GOCC 38 via the GDN 39, to monitor the overall functioning of each satellite 12, including the state of the satellite batteries, to set the gain for the RF signal paths within the satellite 12, to ensure optimum satellite orientation with respect to the surface of the earth, in addition to other functions.

As described above, each gateway 18 functions to connect a given user to the PSTN for both signalling, voice and/or data communications and also to generate data, via database 62 (Fig. 2), for billing purposes. Se-

lected gateways 18 include a Telemetry and Command Unit (TCU) 18A for receiving telemetry data that is transmitted by the satellites 12 over the return link 19B and for transmitting commands up to the satellites 12 via the forward link 19A. The DN 39 operates to interconnect the gateways 18, GOCC 38 and the SOCC 36.

The DN 39 can be implemented as a terrestrial-only data network using wires and/or optical fiber. It is also within the scope of this invention to implement all or a portion of the DN 39 as a wireless link that interconnects the GWs 18, and also possibly the GOCC 38 and SOCC 36, through the constellation of satellites 12. In this regard reference can be had to Fig. 4A, wherein a plurality of gateways 18 are interconnected through space-based RF links that convey the DN 39 via satellites 12, while others are interconnected via a terrestrial data network. In this case the satellites 12 can include a C-band to C-band transponder or, by example, a C-band (uplink) to S-band (downlink) transponder. For this latter case one or more L-band and S-band traffic channels can be allocated for conveying the DN 39, and the GWs 18 then are provided with suitable L-band and S-band transmitter and receiver circuits and antenna(s), respectively, as may be the GOCC 38 and the SOCC 36. In Fig. 4A the satellites 12 may all be non-geosynchronous orbit satellites, while in Fig. 4B at least one of the satellites 12 can be a geosynchronous orbit satellite.

It should be realized that all of the DN 39 can be implemented using the wireless RF links, or only a portion thereof. It should further be realized that the wireless RF links can be used in conjunction with the terrestrial data links to provide redundancy and fault tolerance. Alternatively, certain types of messages and/or status information can be conveyed through the terrestrial data network, while other types of messages and/or status information can be conveyed through the wireless RF data network. Furthermore, all or a portion of the wireless RF links may employ, for example, ground-based microwave links and repeaters, and need not be routed specifically through the satellites. Also, it is within the scope of this invention to employ one or more satellites other than the constellation of communication satellites 12 for conveying the DN 39. By example, and as was shown in Fig. 4B, one or more Medium Earth Orbit and/or geosynchronous satellites can be employed for providing full earth coverage for the DN 39.

In general, each satellite 12 of the LEO constellation operates to relay information from the gateways 18 to the users (C-band forward link 19a to S-band forward link 17a), and to relay information from the users to the gateways 18 (L band return link 17b to C band return link 19b). This information includes SS-CDMA synchronization, paging and access channels, in addition to power control signals. Various CDMA pilot channels may also be used as is described in further detail below. Satellite ephemeris update data is also communicated to each of the user terminals 13, from the gateway 18, via the satellites 12. The satellites 12 also function to

relay signalling information from the user terminals 13 to the gateway 18, including access requests, power change requests, and registration requests. The satellites 12 also relay communication signals between the users and the gateways 18, and may apply security to mitigate unauthorized use.

If used, each pilot channel that is transmitted by the gateway 18 may be transmitted at the same power level, a higher power level, or a lower power level than the other signals. There is a pilot channel on each FDMA channel within each beam. All pilots are derived from a common PN seed code synchronized to GPS System Time. Each gateway 18 applies a time offset to create a PN code with a different phase offset. The time offset is used by the user terminal 13 to determine which gateway is transmitting the pilot. The pilot enables a user terminal 13 to acquire the timing of the forward CDMA channel, provides a phase reference for coherent demodulation, and provides a mechanism to perform signal strength comparisons to determine when to initiate handoff. The use of the pilot channel is not, however, mandatory, and other techniques can be employed for this purpose.

In operation, the satellites 12 transmit spacecraft telemetry data that includes measurements of satellite operational status. The telemetry stream from the satellites, the commands from the SOCC 36, and the communications feeder links 19 all share the C band antennas 12G and 12 H. For those gateways 18 that include a TCU 18a the received satellite telemetry data may be forwarded immediately to the SOCC 36, or the telemetry data may be stored and subsequently forwarded to the SOCC 36 at a later time, typically upon SOCC request. The telemetry data, whether transmitted immediately or stored and subsequently forwarded, can be sent over the DN 39 as packet messages, each packet message containing a single minor telemetry frame. Should more than one SOCC 36 be providing satellite support, the telemetry data is routed to all of the SOCCs.

The SOCC 36 has several interface functions with the GOCC 38. One interface function is orbit position information, wherein the SOCC 36 provides orbital information to the GOCC 38 such that each gateway 18 can accurately track up to four satellites that may be in view of the gateway. This data includes data tables that are sufficient to allow the gateways 18 to develop their own satellite contact lists, using known algorithms. The SOCC 36 is not required to know the gateway tracking schedules. The TCU 18a searches the downlink telemetry band and uniquely identifies the satellite being tracked by each antenna prior to the propagation of commands.

Another interface function is satellite status information that is reported from the SOCC 36 to the GOCC 38. The satellite status information includes both satellite/transponder availability, battery status and orbital information and incorporates, in general, any satellite-related limitations that would preclude the use of all or a

portion of a satellite 12 for communications purposes.

An important aspect of the system 10 is the use of SS-CDMA in conjunction with diversity combining at the gateway receivers and at the user terminal receivers. Diversity combining is employed to mitigate the effects of fading as signals arrive at the user terminals 13 or the gateway 18 from multiple satellites over multiple and different path lengths. Rake receivers in the user terminals 13 and the gateways 18 are employed to receive and combine the signals from multiple sources. As an example, a user terminal 13 or the gateway 18 provides diversity combining for the forward link signals or the return link signals that are simultaneously received from and transmitted through the multiple beams of the satellites 12.

In this regard the disclosure of U.S. Patent No. 5,233,626, issued August 3, 1993 to Stephen A. Ames and entitled "Repeater Diversity Spread Spectrum Communication System", is incorporated by reference herein in its entirety.

The performance in the continuous diversity reception mode is superior to that of receiving one signal through one satellite repeater, and furthermore there is no break in communications should one link be lost due to shadowing or blockage from trees or other obstructions that have an adverse impact on the received signal.

The multiple, directional, antennas 40 of a given one of the gateways 18 are capable of transmitting the forward link signal (gateway to user terminal) through different beams of one or more satellites 12 to support diversity combining in the user terminals 13. The omnidirectional antennas 13a of the user terminals 13 transmit through all satellite beams that can be "seen" from the user terminal 13.

Each gateway 18 supports a transmitter power control function to address slow fades, and also supports block interleaving to address medium to fast fades. Power control is implemented on both the forward and reverse links. The response time of the power control function is adjusted to accommodate for a worst case 30 msec satellite round trip delay.

A synchronizing (SYNC) channel generates a data stream that includes the following information: (a) time of day; (b) transmitting gateway identification; (c) satellite ephemeris; and (d) assigned paging channel. The paging channel conveys several message types which include: (a) a system parameter message; (b) an access parameter message; and (c) a CDMA channel list message. The system parameter message includes the configuration of the paging channel, registration parameters, and parameters to aid in acquisition. The access parameters message includes the configuration of the access channel and the access channel data rate. The CDMA channel list message conveys, if used, an associated pilot identification and Walsh code assignment. The paging channel also conveys a list of neighboring gateways and their pilot signals, as will be described

hereinafter in greater detail.

The access channel is employed by the user terminal 13 to communicate with the gateway 18 when the user terminal 13 is not using the traffic channel. The access channel is used for short signaling message exchanges such as call origination, responses to pages, and registration.

From the access channel the gateway 18 receives and decodes a burst from a user terminal 13 that requests access. The access channel message is embodied in a long preamble followed by a relatively small amount of data. The preamble is the user terminal's long PN code. Each user terminal 13 has a unique long PN code generated by an offset into the common PN generator polynomial.

After receiving the access request, the gateway 18 sends a message on the forward link paging channel acknowledging receipt of the access request and assigning a Walsh code and a frequency channel to the user terminal 13 to establish a traffic channel. Both the user terminal 13 and the gateway 18 switch to the assigned channel element and begin duplex communications using the assigned Walsh (spreading) code(s).

The return traffic channel is generated in the user terminal 13 by convolutionally encoding the digital data from the local data source or the user terminal vocoder. The data is then block interleaved at predetermined intervals and is applied to a 64-Ary modulator and a data burst randomizer to reduce correlation, and thus interference, between return traffic channels. The data is then added to the zero offset PN code and transmitted through one or more of the satellites 12 to the gateway 18.

The gateway 18 processes the return link by using, for example, a Fast Hadamard Transform (FHT) to de-modulate the 64-Ary Walsh Code and provide the de-modulated information to the diversity combiner.

The foregoing has been a description of a presently preferred embodiment of the communication system 10. A description is now made of presently preferred embodiments of this invention.

In a currently preferred embodiment the user terminals 13 are capable of registering with and receiving service from only the satellite system (single mode), or from the satellite system or a terrestrial system (multi-mode). In this latter case one system may be preferred over the other for a first registration attempt. If unsuccessful in obtaining service from the preferred system, the other system can be automatically tried. Reference in this regard can be made to our U.S. Patent Application S.N. 08/707,534, filed 9/4/96, entitled "Automatic Satellite/Terrestrial Mobile Terminal Roaming System and Method", by R.A. Wiedeman and M.J. Sites, incorporated by reference herein in its entirety.

As was indicated previously, the pilot signal is an unmodulated direct sequence spread spectrum signal. The pilot allows the user terminal 13 to acquire the timing of the forward CDMA channel, thereby providing a

phase reference for coherent demodulation while also providing a means for signal strength comparison to determine when to initiate a handoff. Multiple pilots are transmitted by each gateway 18, one in each FDMA channel.

Fig. 5 illustrates three exemplary service areas (SAs) labeled A, B and C. Service area A includes a GW-A 18 that serves SA A and SA C, while SA B is served by a GW-B 18. Also illustrated are three beams associated with satellites A, B and C, specifically outer beams 15 and 12 of satellites A and B, respectively, and inner beam 1 of satellite C. A GW-D 18 is located outside the service areas SA-A, SA-B and SA-C, but within the beam 1 of satellite C. A user terminal 13 is located within SA-A and is within all of the spot beams 15, 12 and 1 of satellites A, B and C, respectively.

It is assumed that the user terminal 13 intends to access the system 10 from an initially unpowered condition. Referring to the logic flow diagram of Figs. 6A and 6B, the following steps are executed by the user terminal 13 in cooperation with the gateway controller 56 of Fig. 2.

At Block A the user terminal (UT) 13 is turned on (a cold start condition). The UT 13 accesses a previously stored indication of a gateway number, such as the last-used gateway, and the primary FDMA channel number for the gateway. In many cases this gateway will be UT's home gateway. At Block B the UT 13 tunes to the channel and attempts to acquire the pilot for the primary FDMA channel, for example, the pilot may be a carrier signal used by the UT 13 to obtain initial system synchronization and to provide time, frequency, and phase tracking. Different pilots can be transmitted with the same code, but with different code offsets, enabling them to be distinguished. If the UT 13 is successful in acquiring the primary FDMA channel, control passes to Block L, as described below. If the UT 13 is unsuccessful in acquiring the primary FDMA channel (and gateway) control passes to Block C where the UT 13 accesses a stored list of channels and tunes to a predetermined channel (e.g., channel 7 of, for example, 13 channels) that is specified as a primary channel.

For example, if the test at Block B fails, the UT 13 may have been carried across the country, or to another country, since the time it was last used. In this case the UT 13 may not find its home gateway 18 when it attempts to access the system 10.

At Block D the UT 13 attempts to acquire the pilot in the channel from the predetermined channel list. If the UT 13 is not successful, control passes to Block D1 to select another channel from the list, and then back to Block C. If the channel list has been exhausted without gaining access to a gateway, control passes to Block D2 where the initial system acquisition procedure is terminated.

Assuming that the UT 13 is successful in acquiring a pilot in a channel from the predetermined channel list at Block D, the UT 13 synchronizes to the pilot, then in

turn accesses the sync channel to gain access to a satellite database and other information. This database facilitates the rapid acquisition of the pilot for future calls. The UT 13 then accesses the paging channel (Block E).

- 5 The operation acquiring these channels may be collectively referred to as receiving a reference signal. From the paging channel the UT 13 can obtain the list of gateways and their respective pilot offsets (Block F). At Block G the UT 13 determines if the UT's home gateway is in the list of gateways. If the UT's home gateway is in the gateway list, the UT 13 goes to the channel specified for the home gateway and acquires the pilot in that channel, and control passes to Block L, as will be hereinafter described so that the UT 13 can access the home gateway.
- 10 If the UT's home gateway is not in the list of gateways control passes to Blocks H, I and I₁, where a gateway is selected (if one is available on the gateway list) and an attempt is made to acquire the selected gateway. If there are no further gateways on the list at Block H, control passes back to Block C.

Referring again to Fig. 5, the selected gateway 18 may not serve the area in which the user terminal 13 is located. By example, the UT 13 is shown as being located within the SA-A, and should be assigned to the gateway A. However, the UT 13 may be receiving the pilot signal in a particular channel of the gateway D through the inner beam 1 of satellite C. Although the UT 13 have also be receiving pilots from gateways A and B, the gateway D is selected because of the higher signal strength of its pilot signal, or because the gateway's pilot signal is the first that the user terminal 13 was able to acquire, or the gateway may be selected based on some other criterion.

- 25 Assuming that this is the first pass through the acquisition procedure, control passes through Block J to Block K to determine if the selected gateway is also the initial gateway that was acquired at Blocks D and E. If yes, control passes to Block M where the UT 13 sends an access request on the specified access channel. If the selected gateway is not the initially selected gateway at Block K, then control passes instead to Block L where the UT 13 acquires the sync and paging channels of the selected gateway, and thus determines the access channel parameters. Control then passes to Block M to send an access request on the access channel to the selected gateway. The access request may be, for example, a request to log-in the UT 13 into the database of active users, or may be a request to initiate a call, or may be both. A call can be made either to one of the terrestrial telecommunications systems that are connected to the gateway 18, such as the PSTN or a private network, or to another user terminal 13 within the service area of the gateway 18, or to any other device that the UT 13 designates.
- 30
- 35
- 40
- 45
- 50
- 55

At Block N the selected gateway, for example the gateway D of Fig. 5, receives the access request from the UT 13. In this embodiment of the invention the selected gateway 18 performs a position location on the

UT 13 using any of various position determining techniques such as multilateral time measurements, reception of UT 13 GPS information, or other means. At Block P the selected gateway 18 makes a determination, based at least in part on the position location, whether to accept or reject the UT 13. Other accept/reject criteria can also be used (e.g., whether or not a roaming agreement exists with the service provider of the user's home gateway). If the UT 13 is accepted, control passes to Block S where the UT 13 is authenticated and, assuming that the UT 13 is authenticated, the UT 13 is added to gateway's VLR54c (Fig. 2) as an active user at this gateway. Control passes to Block T where the gateway notifies the UT 13 of acceptance and, if a call request was sent, begins call setup. At Block U the gateway determines if the UT 13 has initiated a call request. If No, control passes to Block V to enter a standby state waiting for a call request. At Block W the call request is received, and at Block X the gateway 18 assigns one or more traffic channels to the UT 13. The call is initiated and is in progress at Block Y. At Block Z the call terminates, and control passes back to Block V for the gateway 18 to wait for the next call request. If the determination at Block U is Yes, then control passes immediately to Block X to assign the one or more traffic channels to the UT 13.

Referring again to Fig. 5, and assuming for this example that the UT 13 sends an access request to the gateway D, the gateway D determines from the determined location of the UT that the UT is in the SA-A, and that the UT 13 should be assigned to the gateway A. If the UT 13 had instead been determined to be in the SA-C, the UT 13 would still be assigned to the gateway A, which is assumed for this example to also be servicing the SA-C. If instead the UT 13 were to be determined to be located within the SA-B, then the UT 13 would be assigned to the gateway B.

Assuming that the gateway D determines at Block P that the UT 13 is not to be accepted, the gateway D (at Block Q) informs the UT 13 through the forward link, on the paging channel, that the UT 13 is not accepted. The non-acceptance message can also include an identification of a gateway to which the UT 13 should next apply for acceptance, as described above. It is also within the scope of this invention for the gateway D to simply not respond to the access request by the UT 13 which, after a predetermined timeout period, will be informed by default that the UT 13 has not been accepted by the gateway D. The UT 13 after some predetermined period of time will attempt another gateway.

As a result of not being accepted by the gateway D, the UT 13 determines if the gateway that indicated non-acceptance was the initial gateway (i.e., at Block B the Yes path was taken). If Yes, control then passes to Block C. If No, control passes to Block R where the UT 13 removes the previously selected gateway from the list of gateways determined at Block F, and control returns to Block H to select a next gateway from the list. The next

5 gateway can be the gateway having, by example, the next strongest pilot signal. Alternatively, and if the gateway D included a gateway identifier in the non-acceptance message, the UT 13 selects the gateway designated in the non-acceptance message. At Block J control now passes to Block L, and an access request is made to the next gateway at Block M, as previously described.

10 Fig. 7 depicts a further embodiment of this invention, wherein Blocks A-N are as in Fig. 6A. After receiving the access request at Block N, the gateway performs Block S to authenticate the UT 13. At Block U the UT 13 is rejected if not authenticated (Block V). If the UT 13 is authenticated at Block U then Block O is executed to 15 perform a position location on the authenticated UT 13. Processing then continues at Block P, as in Fig. 6B, to determine whether to accept or reject the UT's access request.

20 Reference is now made to Fig. 8 for showing a block diagram of one of the user terminals 13. Coupled to the antenna 13A (which could be comprised of separate transmit and receive antennas) is a satellite RF section having a tunable receiver and transmitter for receiving the downlink satellite transmissions 17B, on various FD channels selectively, and for transmitting the uplink transmission 17A, on various FD channels selectively. A modulator and demodulator (modem) 13C includes suitable spread spectrum circuitry for modulating and spreading the uplink transmissions and for demodulating and de-spreading the downlink transmissions. A controller 13D controls the overall operation of the user terminal 13 and is connected to the modem 13C, to a user interface 13E, to an audio portion 13F, and to a memory 13G. The user interface 13E is coupled to a display (not shown) and user input device, typically a conventional keypad (not shown). The audio portion 13F includes circuitry for driving a speaker and for receiving and digitizing a signal input from a microphone (mic). The memory 13G stores the terminal identifier (ID) and type (e.g., fixed, handheld, etc.), the last channel information that is used at Block B of Fig. 6A, the gateway list that is obtained at Block F of Fig. 6A, satellite ephemeris data, the identifications of assigned gateways, and frequency channels, the assigned spreading code or codes, and any other data and programs required to operate the user terminal 13. A port 25 can also be provided for use in data transmission and reception applications, such as a port that can be connected to a data processor, a facsimile machine, or some other device that sources and/or sinks data.

30 In accordance with an aspect of this invention, each of the gateways 18 of the system 10 includes a capability to receive and accept an access request from a user terminal(UT) 13, and also to receive and reject an access request from a UT 13. If rejecting the access request of the UT 13, the gateway 18 may also provide an indication of another gateway or gateways to which the UT 13 should make a next access request. That is, each

of the gateways 18 is capable of taking an active role in the assignment of a UT 13 either to itself or to another gateway. This functionality is preferably implemented in software executed by the gateway controller 56 (Fig. 2), although dedicated circuitry can also be provided for executing this function either in whole or in part.

While described above in the context of exemplary embodiments of this invention, it should be realized that a number of modifications can be made to these embodiments, and that these modifications will fall within the scope of the teaching of this invention. For example, certain of the blocks shown in Figs. 6A, 6B, and 7 can be executed in other than the order shown, while still obtaining the same result.

Further for example, it should be realized that the gateway 18 can employ a number of different criteria when making a decision as to whether to accept or reject an access request from a given user terminal 13. For example, and in addition to considering the determined location of the user terminal 13, the gateway 18 can also consider one or more of: (a) a current loading of the gateway or a predicted loading of the gateway 18 (as obtained from the GOCC 38 over the DN 39); (b) any impairments in the system, such as in one or more beams of the satellites 12 that are in view of the user terminal 13 that is requesting access (which may also be received from the GOCC 38 or the SOCC 36 over the DN 39); (c) the type of user terminal 13 that is requesting access (i.e., the user terminal 13 may also transmit its type (e.g., fixed, handheld, etc.) when transmitting the access request); (d) the existence of a shared gateway which shares a plurality of service areas; and (e) other criteria, such as the presence of a roaming agreement.

Another criterion upon which to base the acceptance or non-acceptance of the UT 13 is a telephone number sent by the UT 13 with a call setup service request which includes authentication data. For example, and referring again to Fig. 5, if the gateway A can determine from the number that the UT 13 is making a call to is a private or non-public network that is known from database information to be connected to gateway B (but not gateway A), then gateway A may reject the call request, and provide the UT 13 with a gateway list that includes only gateway B. In a similar manner, if the UT 13 is determined to be calling another UT that is known to be in the service area of gateway B, then gateway A may reject the call request, and provide the UT 13 with a gateway list that includes gateway B.

As such, a method is provided for operating a telecommunications system having at least one earth orbiting satellite for conveying signals between a user terminal and one of a plurality of gateways. The method includes the steps of (a) receiving a service request that is transmitted from the user terminal, the service request being received at a first gateway and indicating a destination telephone number to which a call is to be placed; (b) determining if the first gateway is capable of serving

the destination telephone number; and, if not, (c) transmitting a message to the user terminal, the message rejecting the service request and including an indication of another gateway that is capable of serving the destination telephone number. For example, the destination telephone number may correspond to a telephone number of a non-public network, or may correspond to a telephone number of another user terminal.

Another criterion that is based on the number called is a determination by the gateway as to which gateway can complete the call in a most cost-effective manner. For example, assume the UT 13 is in an area of overlapped gateway service and calls a number in country B, but first accesses a gateway in country A. The gateway in country A examines the called number and determines that the user's call will be less expensive if handled instead by the gateway in country B. In this case, the gateway in country A sends a reject message to the UT 13, with an indication to contact the gateway in country B.

As such, a method is provided for operating a telecommunications system having at least one earth orbiting satellite for conveying signals between a user terminal and one of a plurality of gateways. The method includes the steps of (a) receiving a service request that is transmitted from the user terminal, the service request being received at a first gateway and indicating a destination telephone number to which a call is to be placed; (b) determining if the first gateway can connect the call to the destination telephone number at less expense than another gateway can connect the call to the destination telephone number; and, if not, (c) transmitting a message to the user terminal from the first gateway, the message rejecting the service request and including an indication of at least one other gateway that is determined to be capable of connecting the call with less expense than the first gateway.

Although described in the context of a spread spectrum, CDMA system that uses bent pipe LEO satellites, the teachings of this invention are applicable as well to other types of modulation and access schemes, such as Time Division/Multiple Access (TDMA) systems, to satellites that perform on-board signal processing of communications traffic (e.g., regenerative repeaters), and to satellites in other orbital configurations, such as polar-orbiting LEO satellites, elliptically orbiting LEO satellites, satellites in Medium Earth Orbit configurations, and geosynchronous satellites. Furthermore, in some embodiments of this invention some or all of the user acceptance and/or logging-in functions can be performed on-board a satellite, either alone or in cooperation with one of the gateways 18. If the satellites are equipped with inter-satellite links (such as RF or optical links), then information can be passed between the satellites, and the user acceptance and/or logging-in functions as described above can be performed by two or more cooperating satellites, either alone or in combination with at least one gateway 18.

Claims

1. A satellite communications system, comprising at least one satellite, (12), a plurality of gateways (18), and at least one user terminal (13) comprising means for - bidirectionally communicating with at least one of the gateways through said at least one satellite, wherein individual ones of the plurality of gateways comprise means for receiving an access request from said at least one user terminal through the at least one satellite, and further comprise means for notifying the requesting user terminal that the user terminal is one accepted by the gateway for establishing a communication link or not accepted by the gateway for establishing the communication link. 5
2. A satellite communications system as claimed in claim 1, wherein the plurality of gateways (18) are bidirectionally coupled to a data network (39), and wherein the data network comprises at least one of a terrestrial segment (3) and a space segment (1). 10
3. A satellite communications system as claimed in claim 1 or 2, wherein individual ones of the gateways further comprise means for determining a location of a user terminal, and wherein the notifying means is responsive at least in part to the determined location for determining whether to accept the user terminal. 15
4. A satellite communications system as claimed in claim 1, wherein the at least one user terminal comprises means for storing a list identifying individual ones of the plurality of gateways, and wherein the user terminal further comprises means for selecting a gateway from the list to which to send an access request. 20
5. A satellite communications system as claimed in claim 4, wherein the list is received by the user terminal, through the at least one satellite, from one of the plurality of gateways. 25
6. A satellite communications system as claimed in any one of the preceding claims, wherein the at least one user terminal is comprised of means for initially tuning to a frequency channel that was last used by the user terminal and, if the last used frequency channel is not available, for tuning to one or more predetermined channels. 30
7. A satellite communications system, comprising at least one user terminal comprising a first transceiver for transmitting signals, including a request for service signal, to a first RF link and for receiving signals from the first RF link, at least one satellite comprising means for receiving signals from and for 35
- transmitting signals to the first RF link and for transmitting signals to and receiving signals from a second RF link and at least one gateway, the at least one gateway having at least one service area associated therewith and comprising a second transceiver for transmitting signals to and for receiving signals from the second RF link, the second transceiver being bidirectionally coupled to at least one terrestrial communication network for forwarding a communication signal for the at least one user terminal from the at least one communication network to the second RF link and for forwarding a communication signal from the at least one user terminal from the second RF link to the at least one communication network, the at least one gateway further comprising decision means having an input for receiving, from the second RF link, a request for service signal from the at least one user terminal, the decision means operating to determine whether to accept or not accept the request for service in accordance with at least one criterion. 40
8. A system as claimed in claim 7, wherein the at least one gateway further comprises means for determining a location of the at least one user terminal, and wherein the determining means is responsive to the location determining means for determining whether the at least one criterion is fulfilled. 45
9. A system as claimed in claim 7 or 8, wherein the user terminal includes means for receiving, from the first RF link, at least one reference signal that is transmitted by the at least one gateway and wherein the user terminal directs the request for service to a selected gateway based at least in part on at least one received reference signal. 50
10. A system as claimed in claim 9, wherein the at least one user terminal directs a request for service to a gateway selected in accordance with a received reference signal that has a greatest received signal strength. 55
11. A system as claimed in any one of claim 7 to 10, wherein there are a plurality of gateways each of which has a gateway identifier, each of the plurality of gateways further comprising means for transmitting a list comprising at least one other gateway identifier to the second RF link, and wherein the at least one user terminal further comprises means for storing the list that is received from the first RF link. 60
12. A system as claimed in claim 11, wherein the at least one user terminal directs a request for service to a gateway having a gateway identifier in the stored list. 65
13. A system as claimed in claim 8, wherein there are 70

- a plurality of gateways each of which has a gateway identifier, each of the plurality of gateways further comprising means for transmitting at least one gateway identifier to the second RF link for reception by the at least one user terminal when not accepting a request for service from the at least one user terminal, the at least one transmitted gateway identifier being selected at least in part in accordance with the determined location so as to indicate, to the user terminal, a gateway having a service area within which the user terminal is determined to be located.
14. A method of operating a telecommunications system having at least one earth orbiting satellite for conveying signals between a user terminal and one of a plurality of gateways, at least one of the gateways being coupled to a terrestrial telecommunications system, comprising the steps of:
- in the user terminal, attempting to receive a signal from a last-used gateway;
 - if successful, transmitting an access request to the last-used gateway;
 - if unsuccessful, attempting to receive a predetermined communications channel;
 - if successful, obtaining a list of gateways from a gateway transmitting the predetermined communications channel and storing the list of gateways within the user terminal; determining if a predetermined gateway is included within the list of gateways and, if yes, transmitting an access request from the user terminal to the predetermined gateway; and
 - if the predetermined gateway is determined to not be included within the list, selecting one of the gateways from the list and transmitting the access request to the selected gateway.
15. A method as claimed in claim 14, further comprising the steps of:
- at the gateway receiving the access request, and determining a location of the user terminal; determining, based at least in part on the determined location, whether to accept the user terminal for establishing a communication with one of a terrestrial telecommunications system or another user terminal; and
 - if the user terminal is accepted, authenticating the user terminal and assigning at least one satellite traffic channel to the authenticated user terminal.
16. A method as claimed in claim 14, wherein the step of selecting a gateway includes an initial step of acquiring a reference signal from at least some gateways in the list and selecting one of the gateways in accordance with at least one characteristic of the acquired reference signals.
17. A method as claimed in claim 14, and further comprising the steps of:
- at the gateway receiving the access request, performing an authentication of the requesting user terminal;
 - if the user terminal is not authenticated, rejecting the access request;
 - if the user terminal is authenticated, determining a location of the user terminal;
 - determining, based at least in part on the determined location, whether to accept the user terminal for establishing a communication with one of a terrestrial telecommunications system or another user terminal; and
 - if the user terminal is accepted, assigning at least one satellite traffic channel to the authenticated user terminal.
18. A method as claimed in claim 15 or 17, further comprising the steps of:-
- if the gateway determines not to accept the user terminal, notifying the user terminal of nonacceptance;
 - in the user terminal, removing the gateway from the gateway list; and
 - selecting another gateway from the list for making a next access request.
19. A method of operating a telecommunications system having at least one earth orbiting satellite for conveying signals between a user terminal and one of a plurality of gateways, at least one of the gateways being coupled to at least one terrestrial telecommunications system, comprising the steps of:-
- receiving, at a gateway, a service request from the user terminal, the service request passing through the at least one satellite; and
 - based on at least one criterion, notifying the requesting user terminal that the user terminal is one of accepted by the gateway for establishing a communication link or not accepted by the gateway for establishing the communication link.
20. A method as claimed in claim 19, wherein the step of notifying includes a step of assigning at least one satellite traffic channel to an accepted user terminal.
21. A method as claimed in claim 19, wherein the step of notifying includes a step of transmitting an identification of at least one other gateway to a non accepted user terminal, and further comprising the

- step of making a next service request to the identified gateway.
22. A method as claimed in claim 20, comprising the initial steps of:-
- in the user terminal, acquiring a reference signal from a first gateway;
receiving a list identifying at least one other gateway from the first gateway;
receiving a reference signal from the at least one other gateway in the list; and
selecting a gateway having a reference signal with a greatest received signal strength.
23. A method as claimed in claim 19, wherein the at least one criterion includes at least one of a location of the user terminal, a current communications traffic loading of the gateway, a predicted communications traffic loading of the gateway, the presence or absence of any RF impairments, a type of user terminal, a lowest cost routing for a call, a destination for a call, and a presence or absence of a roaming agreement with the requesting user terminal's service provider.
24. A method as claimed in claim 19, and comprising the initial steps of:-
- in the user terminal, acquiring a reference signal from a gateway; and
in accordance with information obtained from the reference signal, transmitting a service request to the gateway.
25. A method as claimed in claim 19, wherein the step of notifying includes a step of not responding to the service request from a non-accepted user terminal, and further comprising the steps of:-
- in the user terminal, waiting for a predetermined period of time to receive a response from the gateway; and
at the expiration of the predetermined period of time, making a next service request to another gateway.
26. A satellite communications system, comprising at least one satellite, a system controller, a plurality of gateways, at least one user terminal comprising means for bidirectionally communicating, with at least one of the gateways through the at least one satellite, and a data network interconnecting the system controller and the plurality of gateways whereby the system controller selectively assigns system resources to individual ones of the plurality of gateways based at least in part on a predicted demand for system resources, the data network being conveyed by one of a wireless network and a combination of a wired network and a wireless network.
- 5 27. A satellite communications system as claimed in claim 26, wherein individual ones of the plurality of gateways are bidirectionally coupled to at least one terrestrial communications system, and wherein individual ones of the plurality of gateways comprise means for receiving an access request from the at least one user terminal through the at least one satellite, and further comprise means for notifying the requesting user terminal that the user terminal is one of accepted by the gateway for establishing a communication link with one of the terrestrial communications network or another user terminal, or is not accepted by the gateway for establishing the communication link.
- 10 28. A satellite communications system as claimed in claim 26, wherein individual ones of the plurality of gateways are bidirectionally coupled to a database of active, logged-in user terminals, and wherein individual ones of the plurality of gateways comprise means for receiving a log-in request from the at least one user terminal through the at least one satellite, and further comprise means for notifying the requesting user terminal of one of: (a) that the user terminal's log-in request has been accepted by the gateway for storage in the database; and (b) that the user terminal's log-in request has not been accepted by the gateway.
- 15 29. A satellite communications system as claimed in claim 26, wherein the wireless network is comprised of RF links between at least one satellite and at least one of the plurality of gateways.
- 20 30. A satellite communications system as claimed in claim 26, wherein the wireless network comprises terrestrial RF links between at least two of the plurality of gateways.
- 25 31. A satellite communications system as claimed in claim 26, wherein the data network transmits information for coordinating the assignment of user terminals to individual ones of the gateways.
- 30 32. A method of operating a telecommunications system having at least one earth orbiting satellite for conveying signals between a user terminal and one of a plurality of gateways, at least one of the gateways being coupled to at least one terrestrial telecommunications system, comprising the steps of:
- receiving a service request that is transmitted from the user terminal; and
based on at least one criterion, determining if

the requesting user terminal is accepted for service and notifying the requesting user terminal that the user terminal is one of accepted for service or not accepted for service, wherein the at least one criterion includes at least one of a location of the user terminal, a current communications traffic loading of the system, a predicted communications traffic loading of the system, the presence or absence of any system impairments, a type of user terminal, and the presence or absence of a roaming agreement with the requesting user terminal's service provider, and wherein the steps of deciding and notifying are executed by one of at least one gateway, at least one satellite, or by a combination of at least one gateway and at least one satellite.

5

10

15

33. A method of operating a telecommunications system having at least one earth orbiting satellite for conveying signals between a user terminal and one of a plurality of gateways, comprising the steps of:-

20

receiving a service request that is transmitted from the user terminal, the service request being received at a first gateway and indicating a destination telephone number to which a call is to be placed;

25

determining if the first gateway is capable of serving the destination telephone number; and, if not,

30

transmitting a message to the user terminal, the message rejecting the service request and including an indication of another gateway that is capable of serving the destination telephone number.

35

34. A method as claimed in claim 33, wherein the destination telephone number corresponds to a telephone number of a non-public network.

40

35. A method as claimed in claim 33, wherein the destination telephone number corresponds to a telephone number of another user terminal.

45

36. A method of operating a telecommunications system having at least one earth orbiting satellite for conveying signals between a user terminal and one of a plurality of gateways, comprising the items of:

50

receiving a service request that is transmitted from the user terminal, the service request being received at a first gateway and indicating a destination telephone number to which a call is to be placed;

55

determining if the first gateway can connect the call to the destination telephone number at less expense than another gateway can connect the

call to the destination telephone number; and, if not,

transmitting a message to the user terminal from the first gateway, the message rejecting the service request and including an indication of at least one other gateway that is determined to be capable of connecting the call with less expense than the first gateway.

60

65

70

75

80

85

90

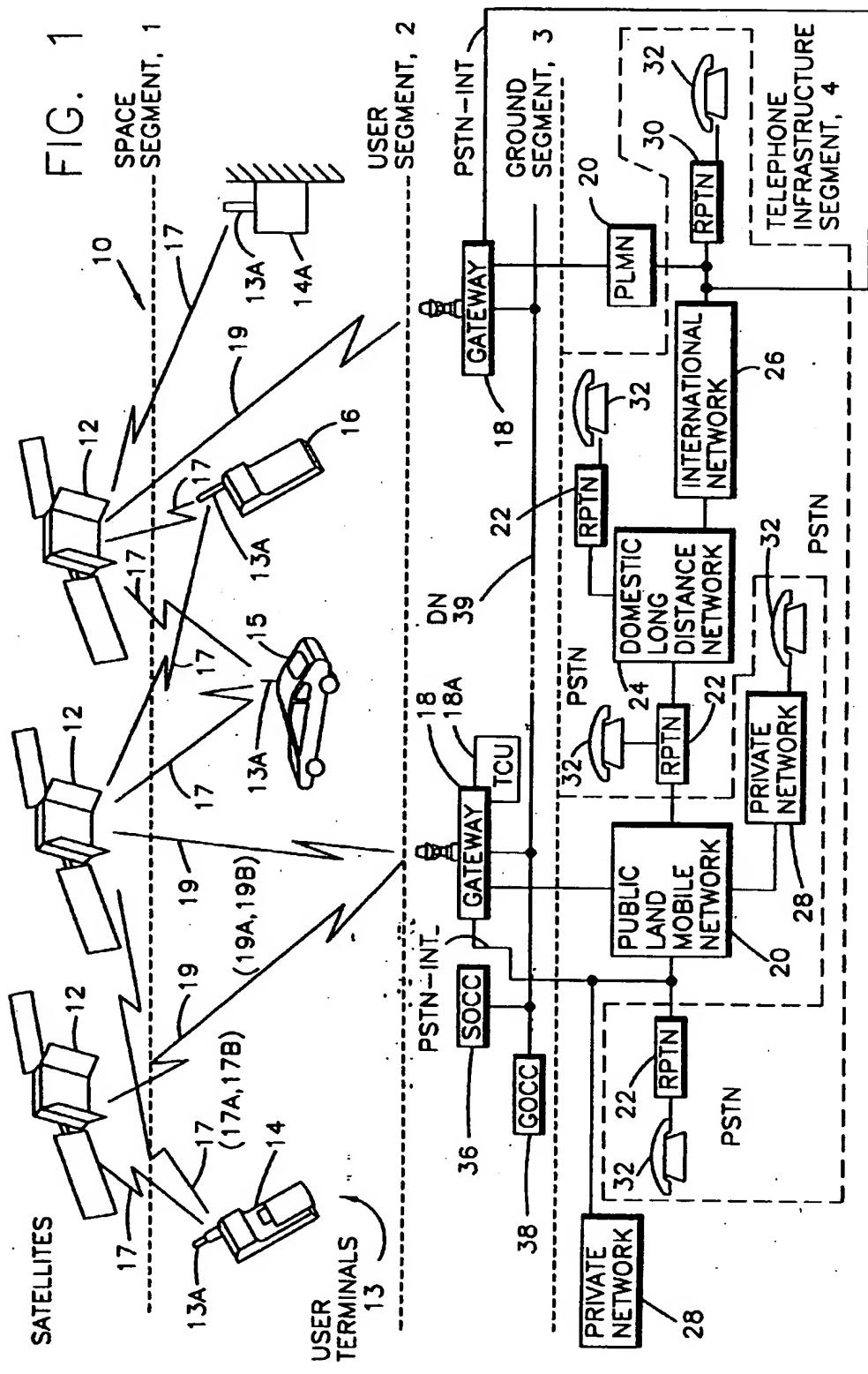
95

100

105

14

1



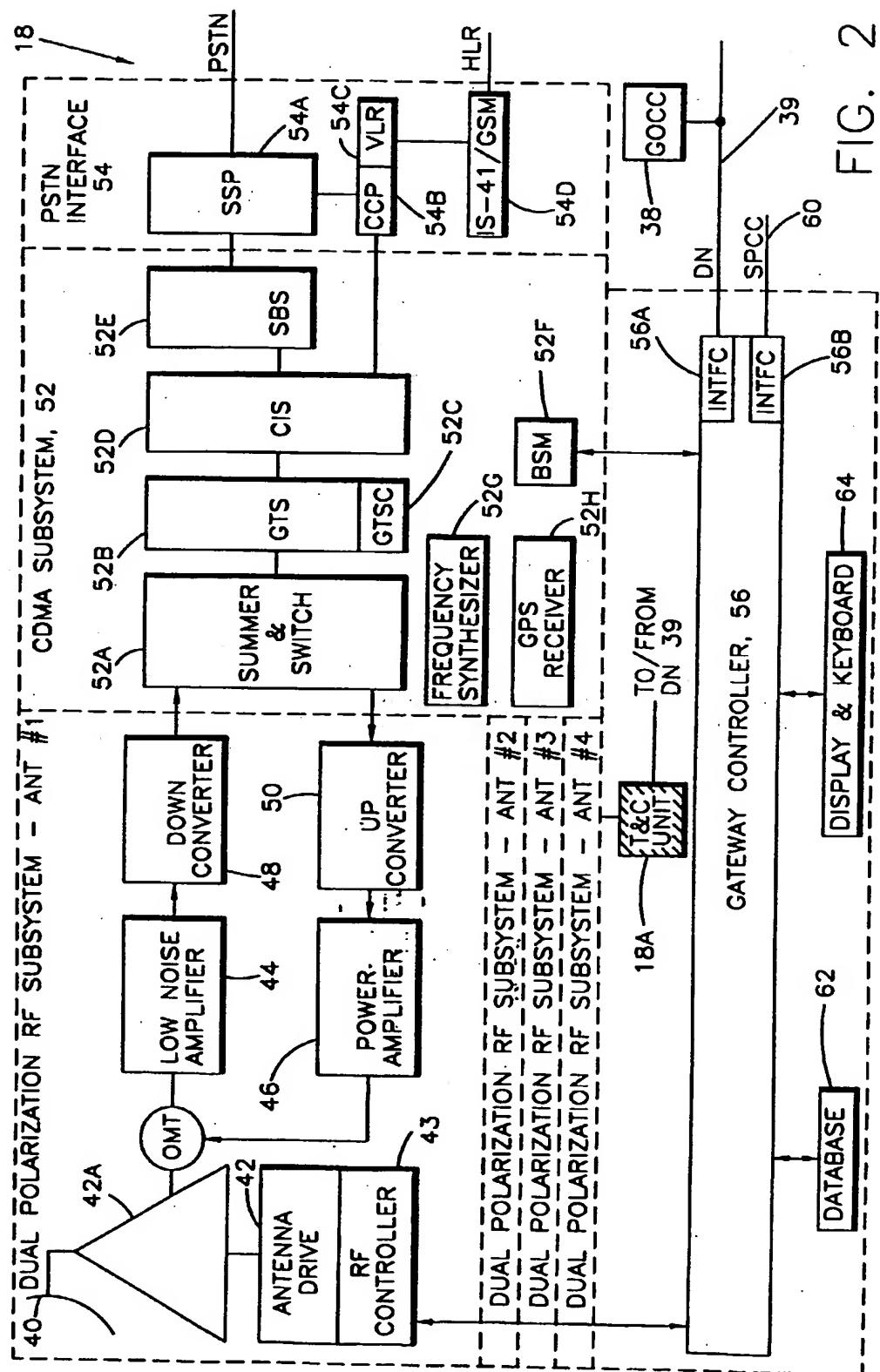


FIG. 2

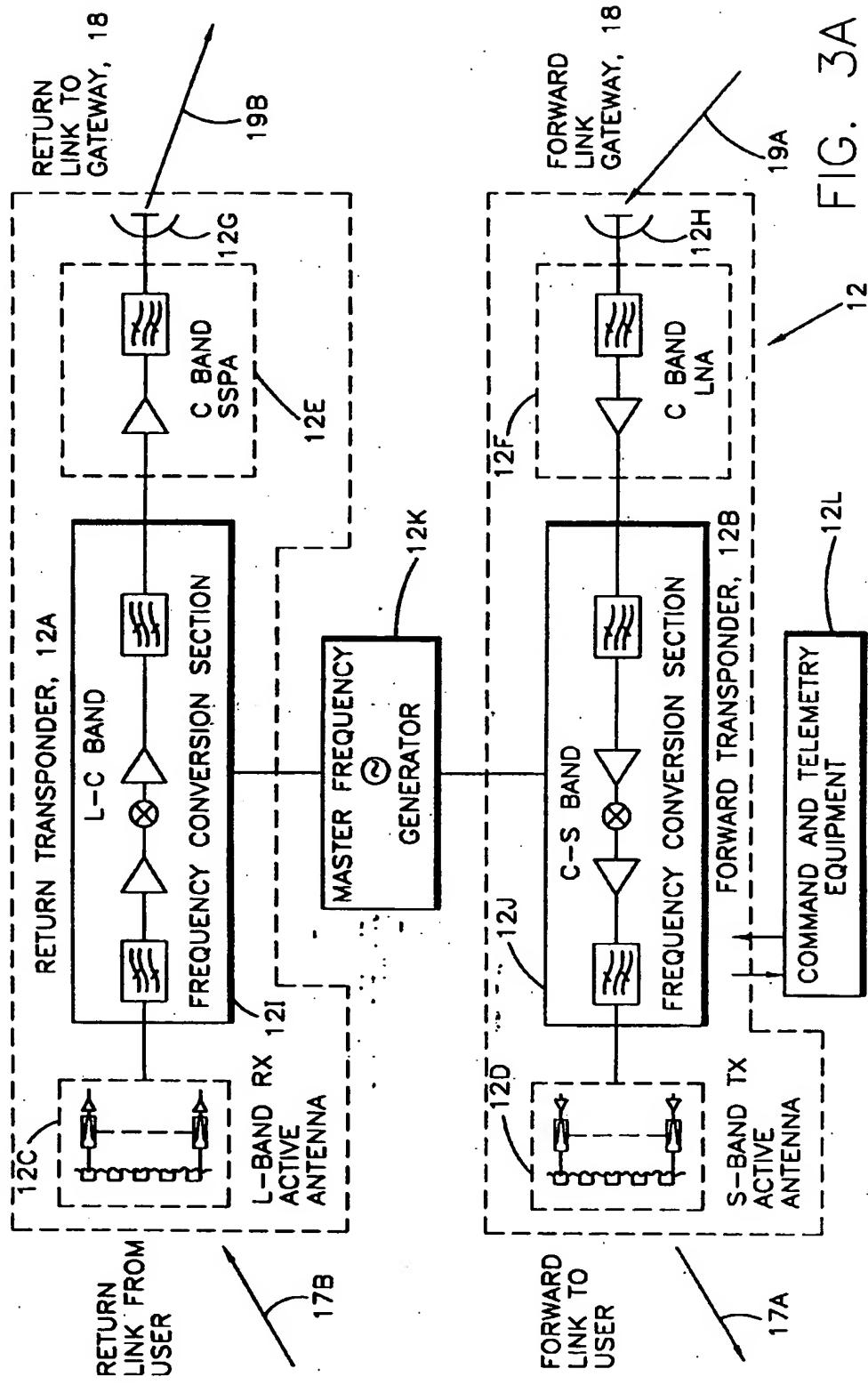


FIG. 3A

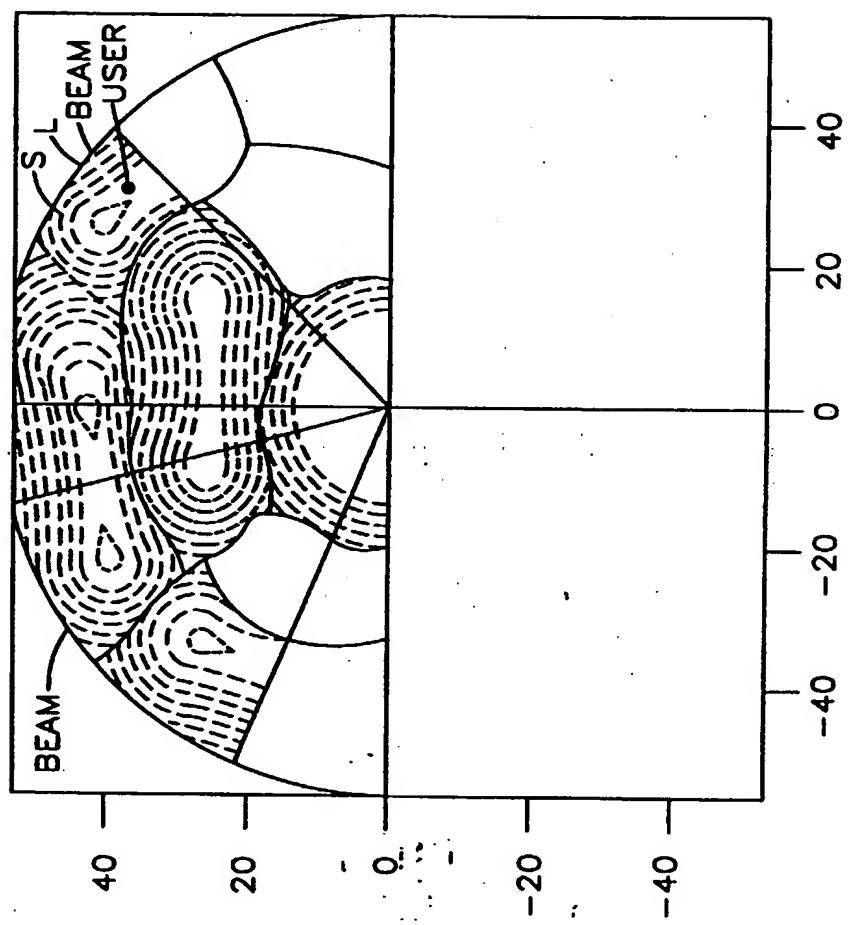


FIG. 3B

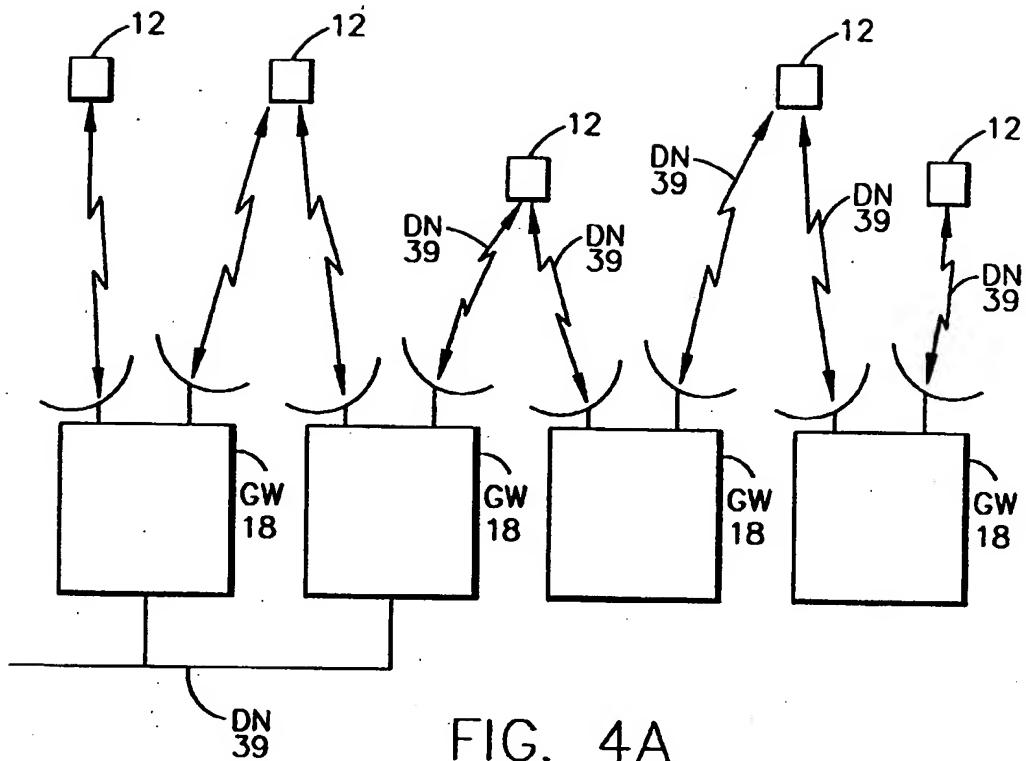


FIG. 4A

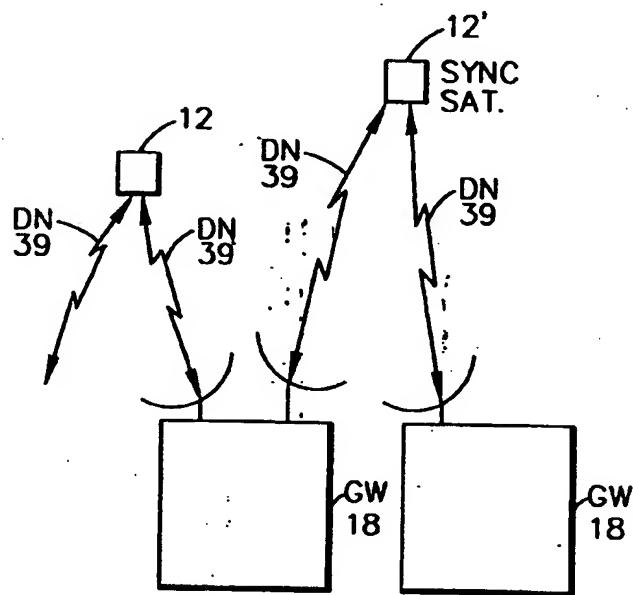


FIG. 4B

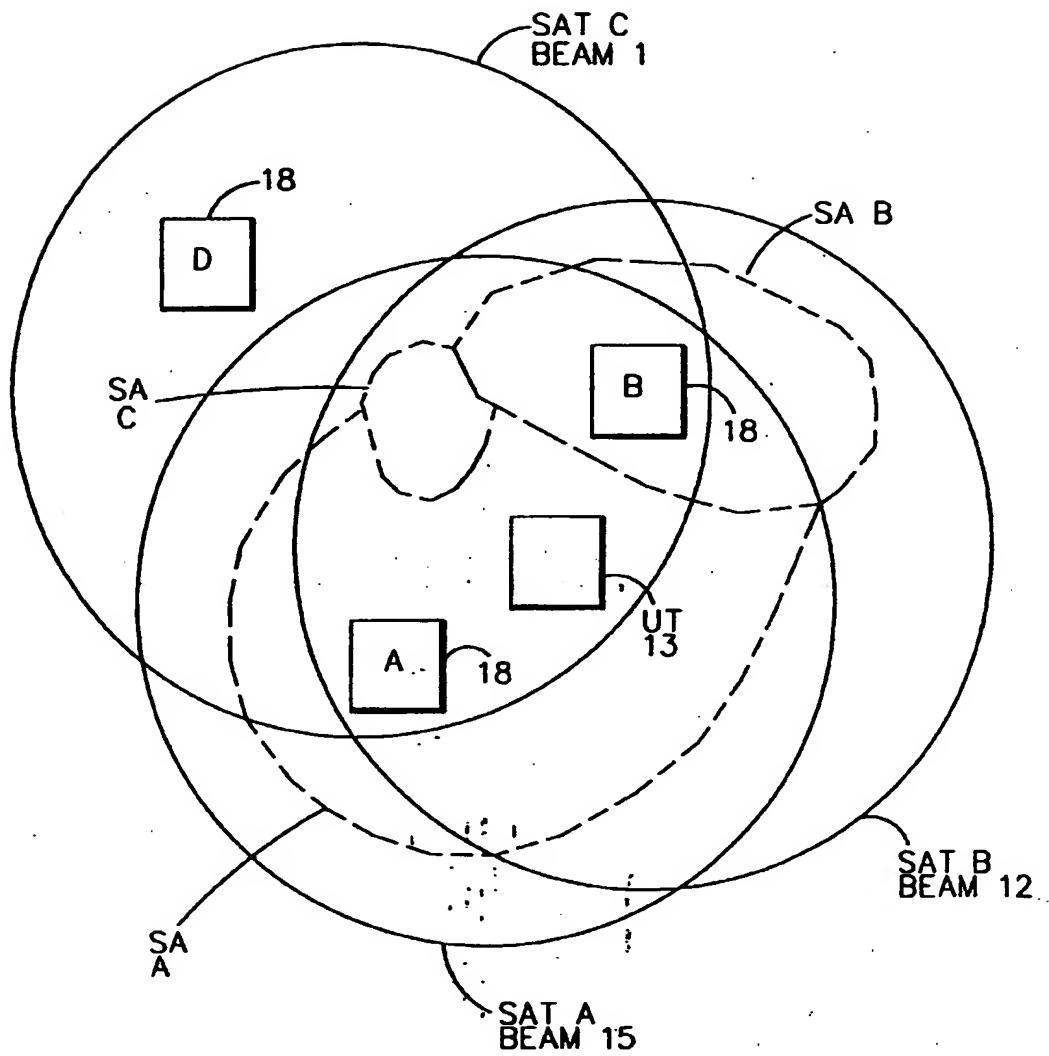


FIG. 5

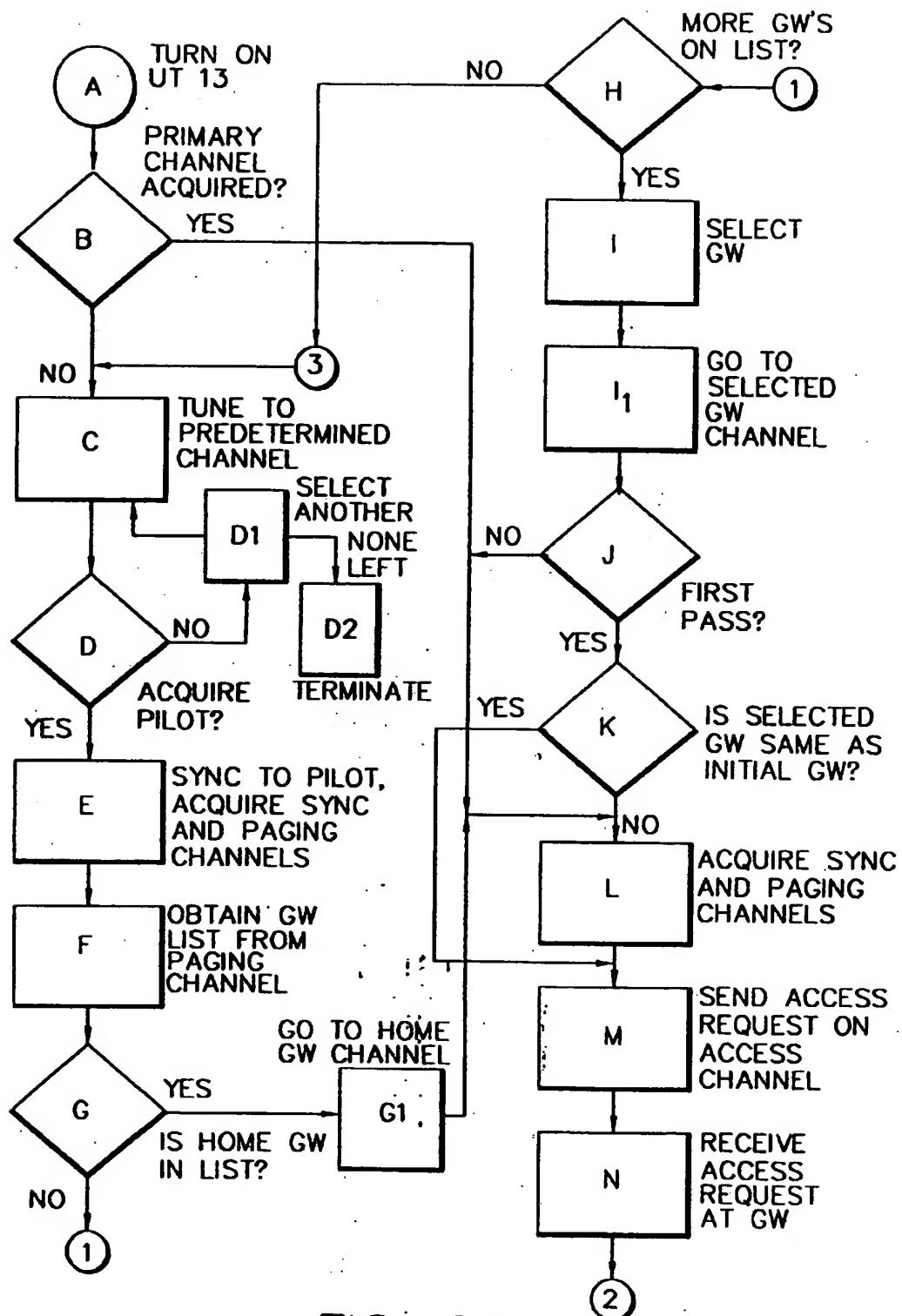


FIG. 6A

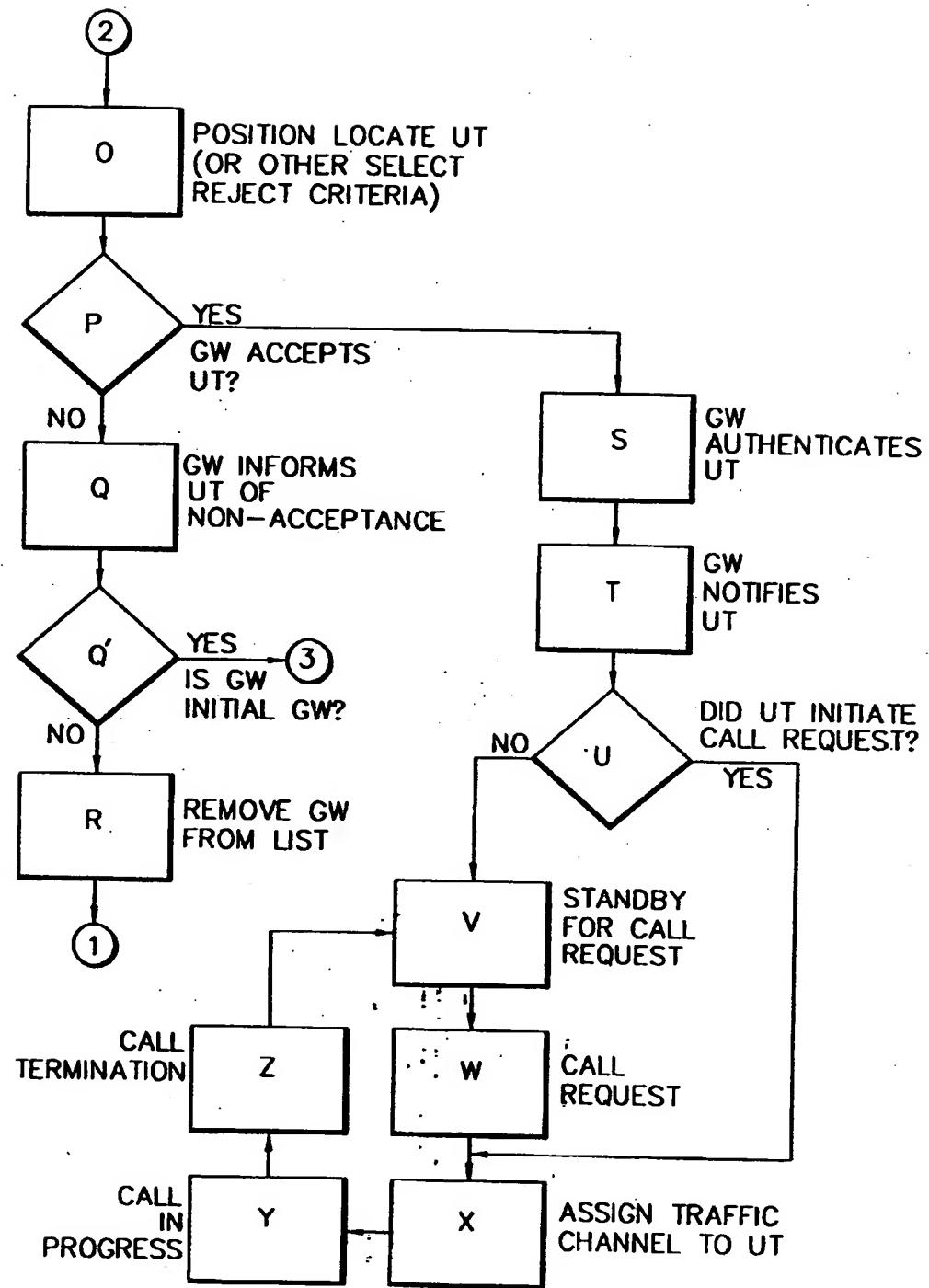


FIG. 6B

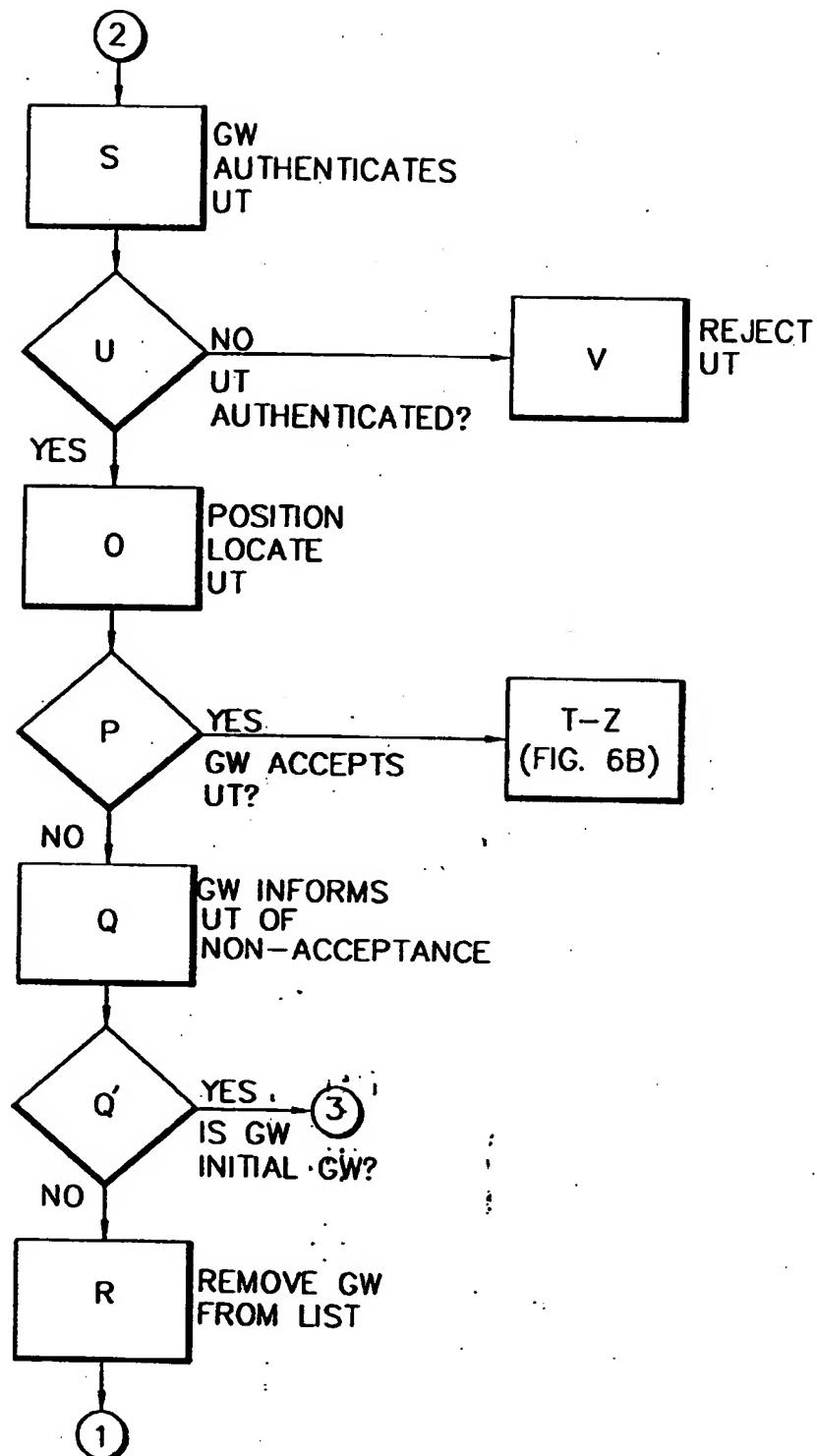


FIG. 7

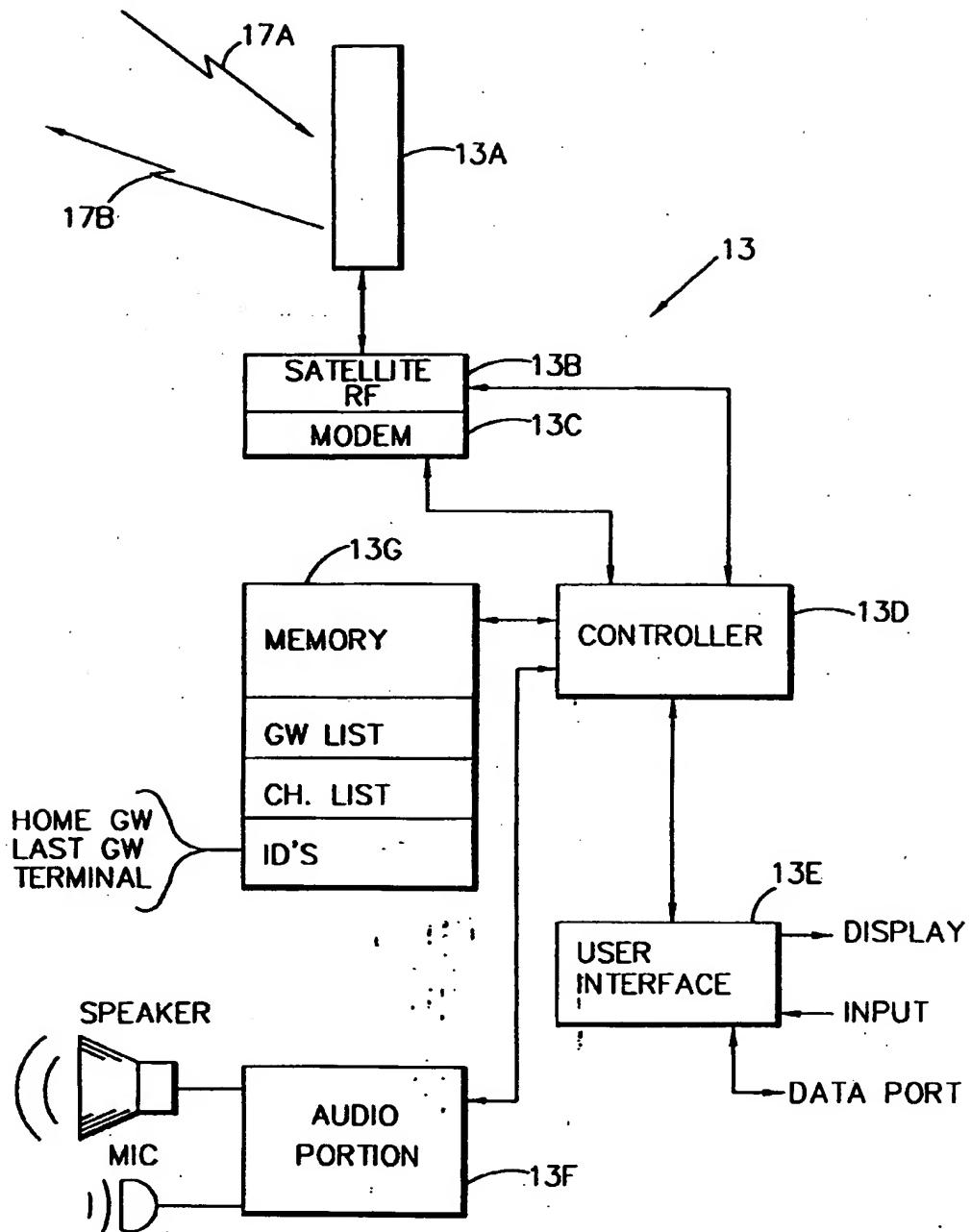


FIG. 8